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Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2012/078

STOCK ASSESSMENT OF NAFO SUBDIVISION 3Ps COD

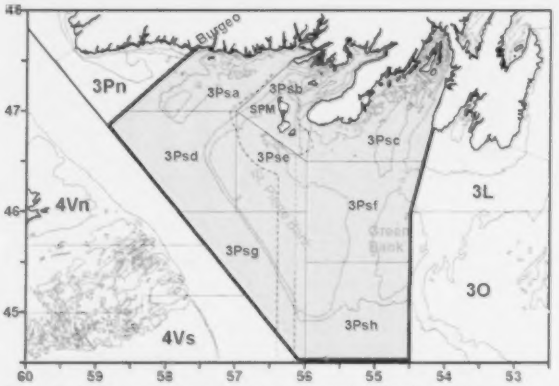

Fig. 1: 3Ps management area (shaded) unit areas (solid lines) and economic zone around the French islands of St. Pierre and Miquelon (SPM) (dashed line).

Context

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Fig. 1).

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those from areas further northward. Female cod from this stock are generally maturing at younger ages in recent years. For example, about 35% of the females are mature by age 5 (~47 cm) in recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The TAC for the 2011/12 and 2012/13 management years was set at 11,500 t. Under the terms of a 1994 Canada-France agreement, the French (St. Pierre et Miquelon) share of the TAC is 15.6%.

The present assessment is the result of a request for science advice from the Fisheries Management (FM) Branch (NL Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

Participants included DFO scientists, a scientist from IFREMER (France), fisheries managers, academia, government officials from the province of Newfoundland and Labrador, and fishing industry representatives.

Canada

SUMMARY

- Information available to evaluate stock status consisted of total commercial landings from all countries (1959 to 2011), log-book data (1997-2011) in conjunction with information from Canadian research vessel (RV) trawl surveys (1972-2012), an acoustic survey conducted in May 2012, sentinel surveys (1995-2012), and a telephone survey of Canadian fish harvesters pertaining to the 2011/12 fishery. Exploitation (harvest) rates were estimated from tagging experiments in Placentia Bay. Consistent with recent assessments, a survey based cohort model (SURBA) was used to infer overall stock trends.

- Recent reported landings have been less than the TAC, and the proportion of the TAC taken has been decreasing. In the 2009/10 season, 78% of the TAC was landed. At the end of the 2011/12 season, just over half (52%) of the 11,500 t TAC was taken.

- Tagging data and ancillary information indicated that there is a complex of stock components in 3Ps. However, the DFO RV survey covers most of the stock, and survey trends broadly reflect stock trends.

- Sentinel gillnet catch rates have been very low since 1999, and the 2011 gillnet index was the lowest in the time-series. Sentinel linetrawl catch rates from the past three years have also been below average. Gillnet catch rates from logbooks of vessels <35' have been stable since 1999. Linetrawl catch-rates decreased over 2006-10, but increased in 2011 and are presently at the time-series average.

- Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay ranged from 17-31% in 2010 but declined to 9-11% in 2011.

- Estimates of total mortality rate from a cohort model (ages 5-10) over 2007-11 plateaued at 0.67. Total mortality rates reflect mortality due to all causes, including fishing. When the age-specific mortality estimates are weighted by the population number at age, total mortality has been decreasing in recent years, with an average value of 0.50 (40% annual mortality). This mortality is relatively high considering that only half of the 2011/12 TAC was taken.

- Recent recruitment (2004-2009 cohorts) has improved. In particular, the 2006 cohort is estimated to be more than twice the time-series (1983-2012) average. This cohort is expected to be fully recruited to the 2012 fishery.

- The basis for a limit reference point (LRP) for this stock is $B_{Recovery}$, defined as the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the limit reference level for this stock.

- Over 2009-2012, SSB has increased considerably. The SSB was estimated to be below the LRP during 2008 and 2009. The 2012 estimate is 64% above the LRP, and the probability of being below the LRP in 2012 is very low (0.01).

- Three-year projections were conducted assuming future mortality rates were within ±20% of current values (2009-11 average). Results indicated that SSB will increase if total mortality is reduced, and remain relatively stable if mortality remains at current levels. SSB is projected to decrease if total mortality is above current values. Overall, the

probability of being below the LRP in 2013 is very low (0.01 to 0.05). By the end of the projection period (2015) the probability of being below the LRP ranges from 0 to 0.16.

INTRODUCTION

History of the fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 84,000 t in 1961 (Fig. 2).

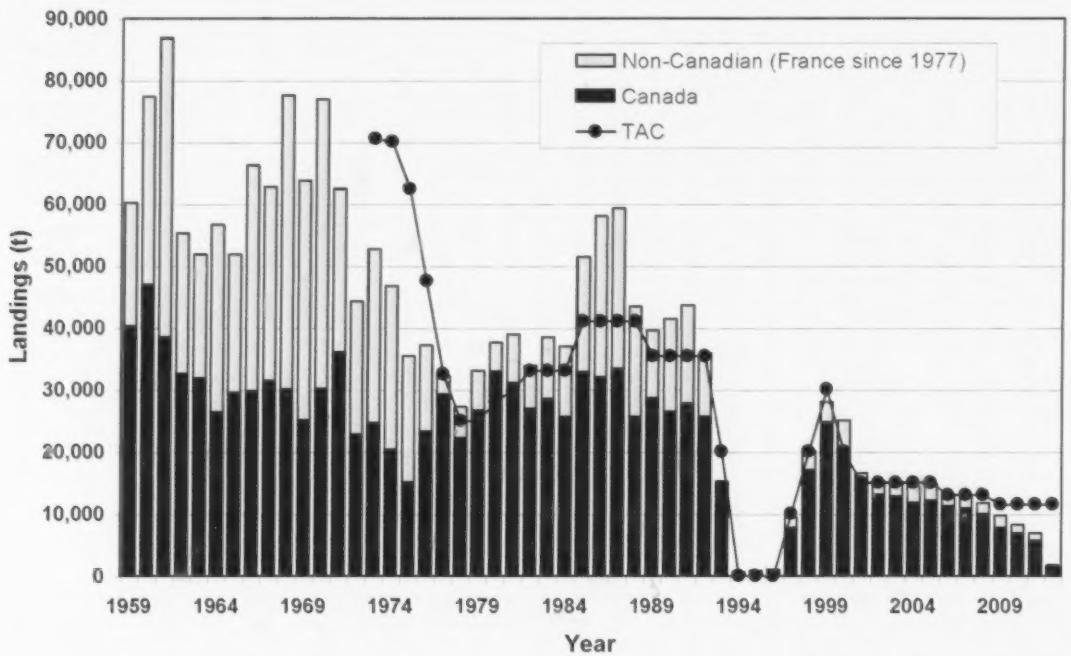

Fig. 2. Reported calendar year landings (t) of cod in 3Ps, 1959-2012 (2012/13 fishing season ongoing). Note that since 2000 TAC's are by management year (1 April-31 March).

After the extension of jurisdiction in 1977, catches averaged around 30,000 t until the mid-1980s when fishing effort by France increased and total landings reached about 59,000 t in 1987. Catches then declined gradually to 36,000 t in 1992.

A moratorium was imposed in August 1993 after only 15,000 t had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year up until the moratorium.

The fishery reopened in May 1997 with a TAC of 10,000 t, and increased to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. TACs and landings over the past decade are shown in Table 1. The TAC for the most recent four management years was set at 11,500 t.

Landings

Table 1: Landings by management year in NAFO Subdivision 3Ps (nearest thousand metric tons).

Management Year	03-04	04-05	05-06	06-07	07-08	08-09[1]	09-10[1]	10-11[1]	11-12[1]	12-13[1,2]
TAC[3]	15.0	15.0	15.0	13.0	13.0	13.0	11.5	11.5	11.5	11.5
Canada	12.6	12.1	11.7	11.3	10.8[4]	10.6[4]	7.5[4]	6.6[4]	4.9[4]	2.0[4]
France	2.4	2.4	2.2	1.9	2.0	2.0	1.5	1.3	1.1	<0.1
Totals	15.0	14.5	13.9	13.2	12.8	12.6	9.0	7.8	6.0	2.0

[1] Provisional.

[2] Approximate landings to 30 September 2012.

[3] TAC is shared between Canada (84.4%) and France (St. Pierre and Miquelon; 15.6%).

[4] Does not include Canadian recreational fisheries.

Beginning in the 2009/10 season, reported landings have been less than the TAC, and the proportion of the TAC not taken has been increasing. In the 2009/10 season, 78% of the TAC was landed. At the end of the 2011/12 season, just over half (52%) of the available TAC was taken. Prior to 2009/10, the TAC was always fully taken with the exception of the initial four years of TAC regulation. Industry participants have indicated multiples reasons contributing to this change, including: reduced profitability, the closure of a processing facility in St.Pierre, and a reduction in the availability of cod inshore which may be in part due to changes in distribution and abundance of prey species (e.g. capelin). Of the 6024 t landed during the 2011/12 season, 4920 t was taken by Canada (including 14 t from sentinel surveys), and 1104 t was landed by France.

Provisional data (as of Sept 30 2012) indicate total landings during the ongoing 2012/13 management year were approximately 2,000 t, 27 t of which was landed by France. Sentinel surveys have landed 8 t to date. These totals are relatively low, and suggest that much of the 2012/13 TAC of 11,500 t will not be caught.

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium. Estimates of recreational fishery landings have not been available since 2006.

During the 2011/12 season, approximately two-thirds of the total landings were taken by fixed gears (dominated by gillnet and linetrawl).

Species Biology

Stock structure and **migration patterns** of 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO RV trawl survey area. These features can add uncertainty to the assessment of stock status. However, since the moratorium, new information has been obtained from various sources, including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several new measures to be put in place to reduce the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing has been delayed until April and winter area closures have been imposed to reduce the possibility that migrant non-3Ps cod are included in surveys and commercial catches. Catches of cod in neighbouring stock areas (3Pn4R and southern 3L) have also been reduced in recent years such that exploitation of migrant 3Ps cod and their inclusion in non-3Ps catches has likely been reduced. The area surveyed during the spring DFO RV trawl survey has also been extended shoreward and total area coverage expanded by 12%. The spring DFO RV trawl survey covers most of the stock and survey trends broadly reflect stock trends.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at younger ages has been higher for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. A recent review of spawning time (DFO, 2009) found no indication of any shift in the timing of spawning compared to previous observations.

Growth, calculated from length-at-age in research trawl survey samples, has varied over time. For ages older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, but data from 2007-11 surveys suggest that mean length at age for ages 3-8 has been near average. Length-at-age for fish sampled in the sentinel survey has declined since 1998 in fish ages 4 and older.

Comparison of post-1992 **condition** with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. Body condition in 2012 was slightly below average, while liver condition was below most of the values from 1997 to 2007. Seasonally, fish and liver condition observed in sampling from the sentinel surveys were higher in the fall and declined over the winter and early spring. Annually, trends in condition have varied, and sentinel sampling in 2011 indicates condition was below the time-series average.

An age reading workshop was held in St-Pierre and Miquelon in September 2012, gathering Canadian and French cod otolith readers. During this workshop, several biases were identified when comparing otolith readings, including a bias between 2 readings with different methods from the same reader. The position of the first ring was identified as an important source of bias. Some measurements were taken on otolith images with 100% agreement from the IFREMER software package TNPC in order to determine distances between nucleus and the settling check, and also from the nucleus to the two first growth rings. Distance analysis is generally

used to identify mismatches between readings and/or readers. The second important source of bias was the difference in the edge interpretation during July and August. Ages assigned by the Canadian personnel are generally one year greater than those of participants from France for those months. In order to reduce this bias, a guideline on reading methods was discussed and a database of reference otolith images was initiated (where 100% agreement was reached).

This first Franco-Canadian meeting on age estimation has identified sources of biases and helped to reduce them. It also produced reference documents common to France and Canada for cod in the Northwest Atlantic (Mahé et al, in press). However some differences persist, mainly on the otoliths sampled in July and August and future work on these differences should be part of future studies.

ASSESSMENT

Resource Status

Sources of information:

Stock status was updated using total **commercial landings** to September 2012, log-book data (1997-2011), **abundance indices** from Canadian research vessel (RV) trawl surveys (1972-2012), and sentinel surveys (1995-2012). Results of a telephone survey of inshore fish harvesters from Canada and exploitation (harvest) rates estimated from tagging experiments in Placentia Bay were also available.

Research vessel surveys:

Canadian DFO RV bottom **trawl surveys** have been conducted since 1972. Surveys from 1972-82 had poor coverage. The surveyed area was increased by 12% during 1997 when inshore strata were added. The DFO RV survey was not completed in 2006 due to unforeseen operational difficulties with the vessels. Survey indices are presented for the expanded DFO survey area (inshore and offshore; denoted "Combined" in figures) as well as for the offshore strata ("Offshore" in figures). The DFO RV survey covers most of the stock, and survey trends broadly reflect stock trends. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shore-ward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shore-ward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but declined from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period up to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. The survey index shows a general declining trend from 87,000 t in 2001 to 20,525 t in 2008, though the subsequent trend is less clear. Most of the recent points are near average; in 2012, the survey biomass index was 44,700 t. Survey catches were highest on Burgeo Bank, the southern edge of the Hermitage Channel and the Halibut Channel. Survey biomass from the combined index ("All Strata <300 fms") shows similar trends to the offshore only index.

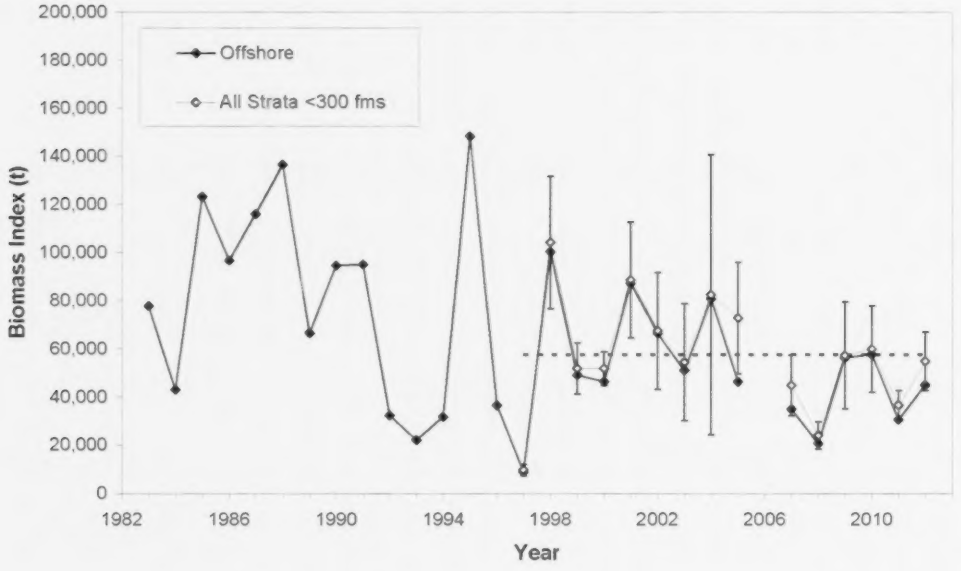

Fig. 3. Research vessel survey biomass indices (t) (error bars are 95% confidence intervals for combined survey index – dashed line is average of combined survey index).

An index of **mature (adult) biomass** was computed from the offshore survey (Fig. 4) and current values are below the time-series average.

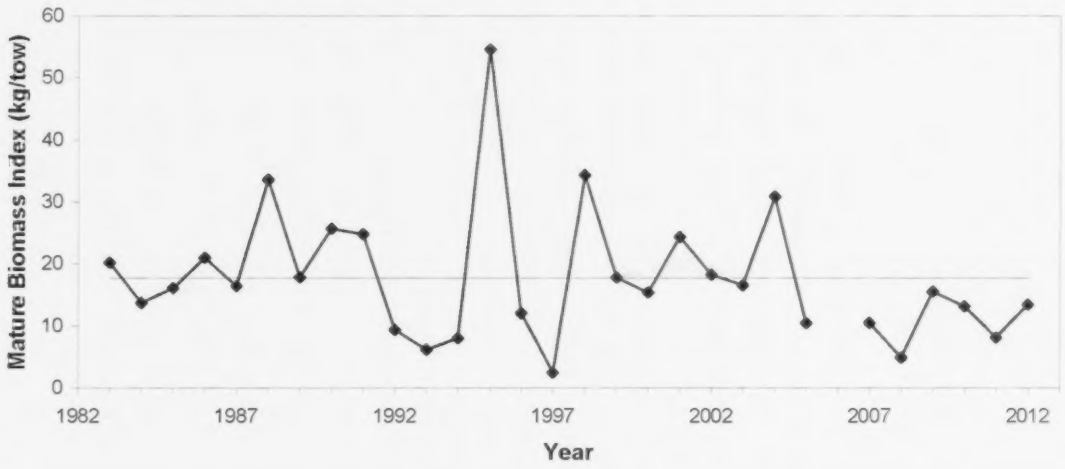

Fig. 4. Mature biomass index from DFO RV offshore survey. Dashed line is the time-series average.

The offshore DFO RV abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 5). The index generally declined from 88.25 million fish in 2001 to 38.65 million in 2008. Due to increased abundance of young cod (less than age 5), the index increased to 88.49 million fish in 2010. The 2011 index value was near the time-series average, but increased slightly in 2012 (74.66 million). The combined DFO RV abundance index ("All Strata" series; Fig. 5) shows similar trends to the offshore index, but has a larger increase from 2011 to 2012 due mainly to survey catches within Fortune Bay and along the inner Hermitage Channel.

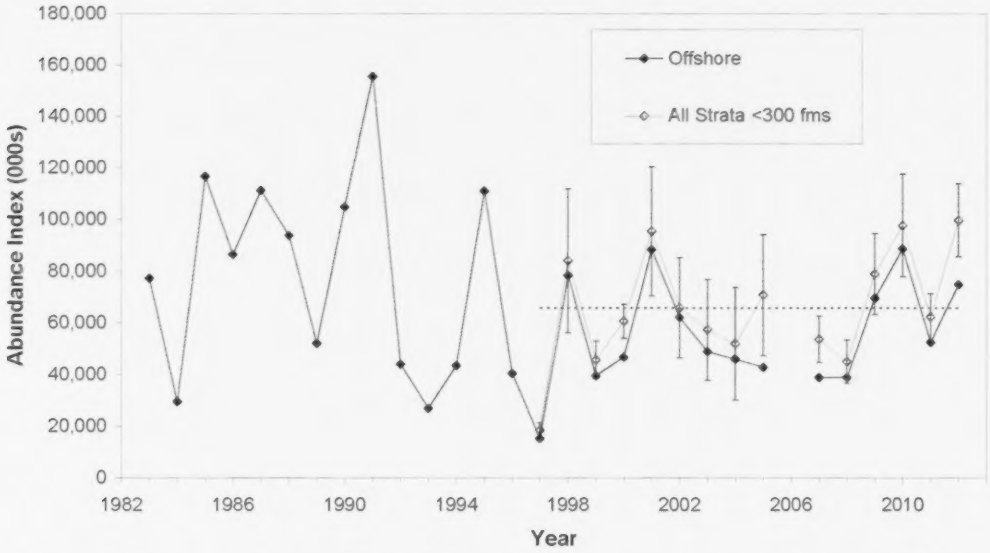

Fig. 5. Research vessel survey abundance indices (error bars are 95% confidence intervals for combined survey – dashed line is average of combined survey index).

Age Composition:

Catches during the 2012 RV survey consisted mainly of cod aged 1-5 (82% of abundance index). The 2006 year-class, now six years old, is near the average of previous age 6 observations. The age 1 index in 2012 is very large, at approximately five times the 1983-2012 age 1 average. Further, catches of age 1's were widely distributed throughout the survey area. However, it is noted that age 1 survey indices are not always a strong predictor of survey trends for subsequent ages and the strength of this year-class remains to be confirmed.

Cohort Analysis Reference Points:

The basis for a limit reference point (LRP) for this stock is $B_{Recovery}$, defined as the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the LRP for this stock (DFO, 2004). Removal reference points have not been identified for this stock.

Spawning Biomass:

Cohort analyses (Cadigan, 2010) of the DFO RV data indicated that spawning stock biomass (SSB) declined by more than 60% over 2004-09 (Fig. 6). Median SSB was estimated to be below the LRP in 2008 and 2009. Over 2009-2012, SSB has increased considerably, and the 2012 estimated is 64% above the LRP. The probability of being below the LRP in 2012 is very low (0.01). As a result of improved recruitment and recent increases in the proportion mature at age, 77% of the 2012 SSB is comprised of younger (age 5-7) fish.

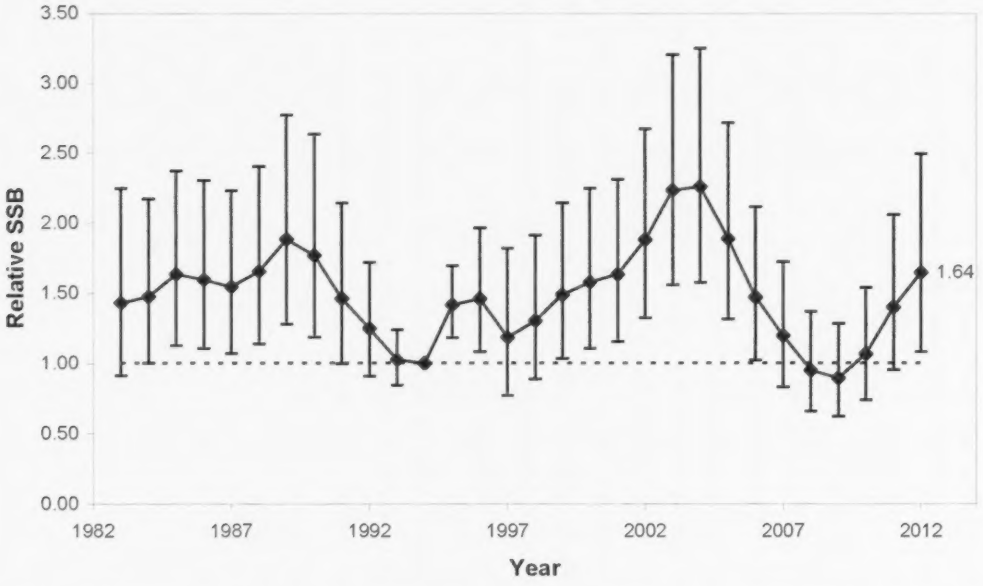

Fig. 6. Cohort analysis estimates of Survey Spawning Stock Biomass (SSB), relative to the 1994 value (median estimate with 95% confidence intervals). A horizontal dashed line at one (reference level) represents the SSB Limit Reference Point. Text label indicates the current SSB relative to the LRP.

Mortality Rates:

Estimates of total mortality from the cohort model (Fig. 7) over 2007-11 (ages 5-10) averaged 0.67 (49% mortality). This high level of mortality is a concern. Total mortality rates reflect mortality due to all causes, including fishing. Current estimates of mortality over ages 5-10 vary from 0.33 (28% mortality) at age 5 to 0.85 (58% mortality) at ages 8 and 9. When the age-specific mortality estimates are weighted by the population number at age, total mortality has been decreasing in recent years, with an average value of 0.50 (40% annual mortality). The population-weighted mortality has been decreasing since 2006 as the fraction of older fish in the population has been reduced. Current levels of mortality are relatively high considering that only half of the 2011/12 TAC was taken.

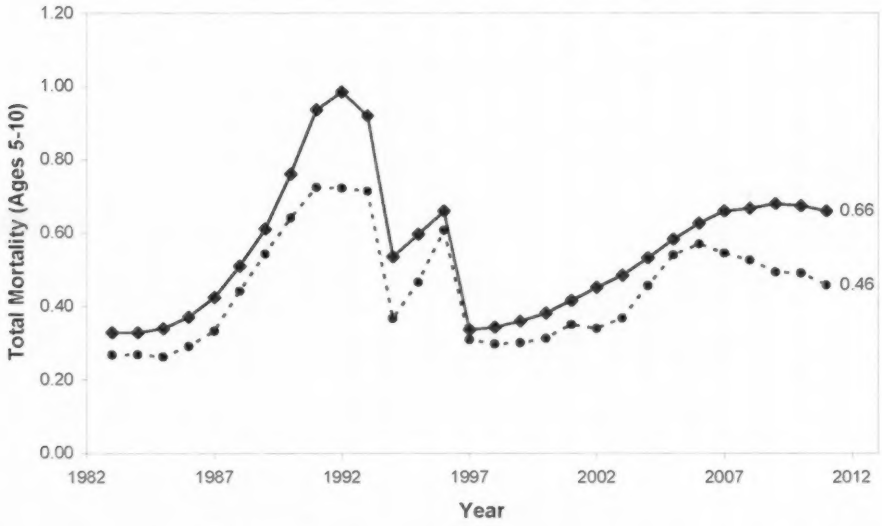

Fig. 7. Cohort analysis estimates of total mortality over ages 5-10. Solid line: average annual mortality; dashed line: average annual mortality weighted by population size at ages 5-10. Text label indicates the estimated total mortality for 2012.

This analysis assumes that age 4 and older fish are equally selected (flat-topped) by the RV survey. Alternate assumptions for the relative catchability (domed) of cod ages 4+ were explored in a previous assessment and gave similar trends (see DFO, 2009). Flat-topped selectivity is commonly assumed unless there is evidence otherwise.

Recruitment:

Estimates of recruitment (at age 1; Fig. 8) from the cohort model indicate that the 2006 cohort is estimated to be relatively strong, comparable to the 1989 cohort. Several successive cohorts (2004-2009) are estimated to be much improved compared to the preceding five estimates. The exceptionally high estimate of the 2011 year-class is based upon only the 2012 age 1 survey data; the degree to which this year-class will recruit to the fishery remains to be confirmed as additional data are collected.

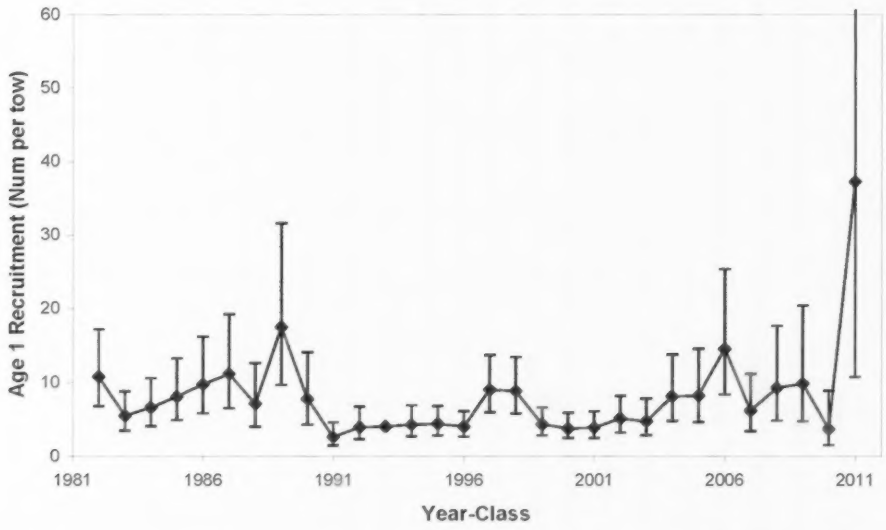

Fig. 8. Estimated relative year-class strength from cohort model (with 95% confidence interval).

Projection:

Three-year projections were conducted assuming future mortality rates were within ±20% of current values (0.67; the 2009-2011 average). Results indicated that SSB will increase if total mortality is reduced, and remain relatively stable if mortality remains at current levels. SSB is projected to decrease if total mortality is above current values. Overall, the probability of being below the LRP in 2013 is very low (0.01 to 0.05). By the end of the projection period (2015) the probability of being below the LRP ranges from 0 to 0.16.

Sentinel survey:

Fixed gear **sentinel surveys** have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2012. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2012 is still ongoing; hence, the data for 2012 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates.

The standardized total annual **catch rate** for gillnets was high from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2011 (Fig. 8, upper panel). The 2011 results are 40% lower than the 2010 values; and are the lowest of the time-series. The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). Most recent values are amongst the lowest in the time-series. Although considerable declines have been measured by both gear types, the magnitude of this decline is inconsistent across gear types. Current gillnet estimates are 6% of the 1995-97 average, whereas current line-trawl values are 39% of the first two estimates.

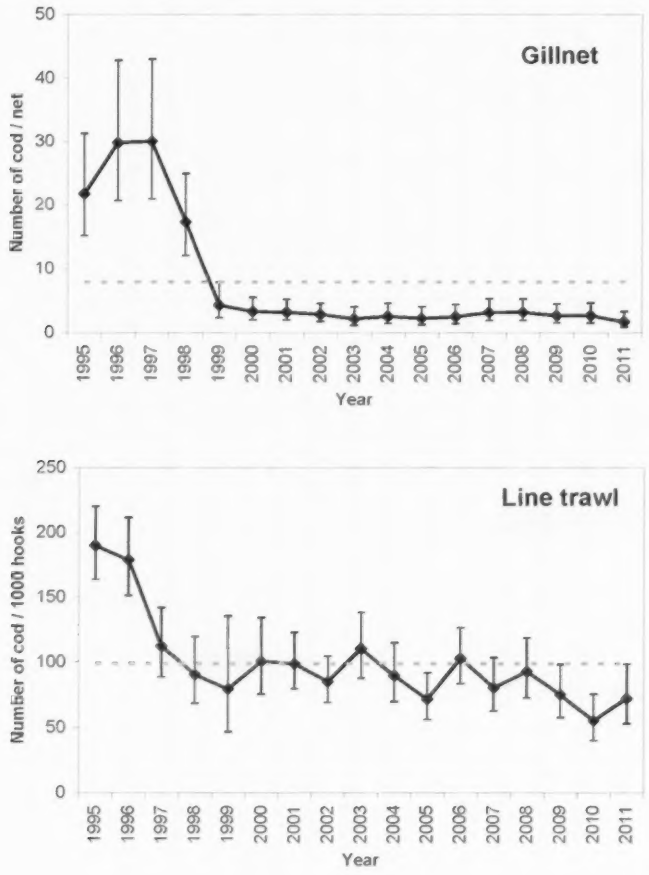

Fig. 9. Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Comparison of sentinel catch rates and the DFO RV index at times show inconsistent age-compositions. This may be indicative of differences in cohort strength between stock components.

Age composition:

The standardized age-specific catch-rates for gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the sentinel catch-rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is unclear.

Acoustic Survey:

Results of an acoustic conducted by the Centre for Fisheries Ecosystem Research (Memorial University) during May 2012 were presented and discussed; results are still considered preliminary and analyses from this survey are ongoing.

Log books:

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in the nature of the fishery than changes in population size.

<35' Vessels:

Standardized annual catch rates from science log books (<35' sector) for vessels fishing gillnets show a declining trend during 1998-2000, but have subsequently been fairly constant (Fig. 9, upper panel). Linetrawl catch rates show a much different pattern with a greater degree of variation during the past decade (Fig. 9, lower panel). After peaking in 2006, linetrawl catch rates generally declined to 2010, and in 2011 show some increase and are near the time-series average. The commercial catch-rate index is based on weight of fish caught whereas the sentinel index is based on numbers. As with the sentinel results, there is contrast between the two gear-types in current catch rates relative to the beginning of the time-series. Compared to the average CPUE in 1997 and 1998, current gillnet CPUE is 50% lower, whereas the 2009 linetrawl CPUE is only about 15% below the initial values. Traditionally most gillnet effort was within the eastern part of the stock area; similarly linetrawl was the dominant gear in western 3Ps. However, based upon the logbooks returned in 2009 and 2010, gillnet activity in the inshore was equally spread between eastern and western 3Ps, due to significant reductions in effort throughout eastern 3Ps. In 2011, more than half of the gillnet effort inshore was within Fortune Bay and westward, again due to reductions in effort in the eastern portion of the stock area. Due to declines in the return rate of these logbooks over time, it is unclear if these trends reflect the fishery as a whole.

The percentage of the catch from the <35' sector that is accounted for in the standardized logbook indices has declined over time and now represents less than 30% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality, and comparability, of this index over time.

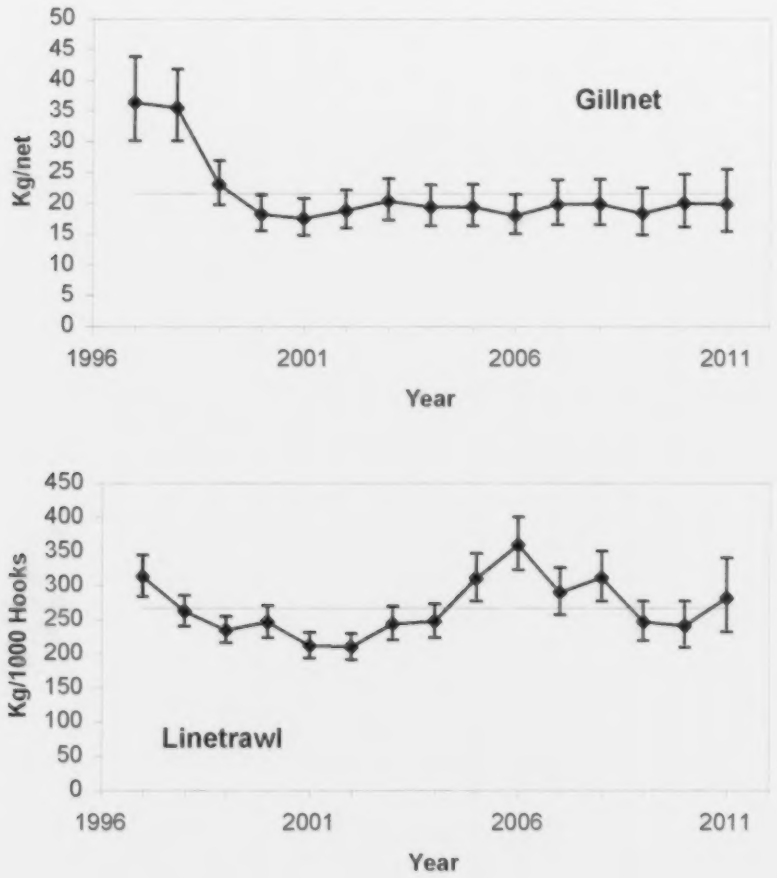

Fig. 10. Standardized catch rates for gillnets and line-trawls from science log books for vessels <35'. Error bars are 95% confidence intervals; dashed line is the time-series average.

Tagging:

During 2008-11, tagging was conducted in Placentia Bay in spring (May-June). Although exploitation rates based on tagging of cod in Placentia Bay may not be applicable to other areas, or to the stock as a whole, this area accounts for a significant portion (~ 25-30%) of the overall annual landings from the stock.

Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay ranged from 17-31% in 2010 but declined to 9-11% in 2011. Estimates of exploitation rates from tagging can be influenced by the sizes of cod tagged due to selectivity of commercial fishing gear. Larger cod (>65 cm) tend to be more readily selected by gill nets compared with smaller ones.

Release of tagged cod has been reduced in recent years and exploitation rates based on tagging are no longer available for the offshore (Halibut Channel and Burgeo Bank), Fortune Bay, or Hermitage Bay.

Sources of Uncertainty

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. In assessing stock status, it would be useful to quantify the accuracy of total removals, especially in the post-moratorium. Estimates of recreational fishery landings have not been available since 2006.

There is uncertainty regarding the origins of fish found in 3Ps at various times of the year. Tagging and telemetry experiments show that there is mixing with adjacent stocks (southern 3L and 3Pn4RS) and this may vary over time.

Comparison of sentinel catch rates and the DFO RV index at times show inconsistent age-compositions. This may be indicative of differences in cohort strength between stock components. For example, the sentinel gillnet data consistently measured the 1992 cohort as being an above average fraction of the annual catch. This cohort was also important to the commercial gillnet catch, but was not notable in the DFO RV index. A similar phenomenon exists for the 2004 cohort (detected by sentinel linetrawl but not sentinel gillnet or DFO RV index).

The geographical coverage of tagging since 2007 is very limited; during 2008-11 cod have only been tagged in Placentia Bay. The lack of recent tagging in other areas adds uncertainty to our understanding of natural mortality rates, exploitation rates, stock structure, and movement patterns and how these influence survey and commercial catch rates in the recent period.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in recent assessments and yielded similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. In the 2009 DFO RV survey, the estimated abundance at ages 2-8 increased compared to these cohorts at ages 1-7 as measured in the 2008 survey. This is unusual and indicates that one (or possibly both) of the 2008 and 2009 surveys may be influenced by a year-effect. Year-effects are also evident in the 1995 and 1997 survey results.

The percentage of the catch from the <35' sector that is recorded within the logbook database has declined over time and now represents only about 45% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality and comparability of the standardized catch-rate index derived from this data over the time-series.

Age at 50% maturity has been declining in recent years. The proportion of female cod maturing at younger ages has been higher for all cohorts subsequent to the 1986 cohort, resulting in a significant proportion of SSB made up of younger fish. Questions exist as to whether or not these small, young fish are effective spawners.

As a result of improved recruitment and recent increases in the proportion mature at age, 77% of the 2012 SSB is comprised of younger (age 5-7) fish, which is relatively high.

ADDITIONAL STAKEHOLDER PERSPECTIVES

Fishing effort and landings have declined in the past number of years mainly due to the price and the increased bait and fuel costs. Fish Harvesters are concerned about the low abundance of capelin and the impact it is having on cod migration and negative impacts the low abundance will have on the health and reproduction of cod. There is growing concern that the expanding population of grey seals will have negative impacts on cod abundance.

Fish harvester's perspectives were compiled based on the results of the 2011 fishery. A telephone survey was conducted by the FFAW during February of 2012. Most fish harvesters felt that the 2011 abundance was about the same or less when compared to 2010. Fish harvesters were asked to rate their 2011 catch rates in comparison to his/her historical perspective; with 1 being the worst and 10 being the best, most responses ranged from 5 to 8. The size range of cod observed in 2011 was mostly an even mixture of all sizes and size range observed from the 2010 to 2011 fishing season was the same size. An overwhelming majority of fish harvesters stated the condition or health of cod was good. The majority of fish harvesters felt that the baitfish, capelin, herring, squid and mackerel were at a low level and declining.

Fish harvesters in the >20m vessel sector, during the 2011 fish season saw a decline in the abundance of the older (larger) fish in the offshore catch. They also saw evidence of the strong 2006 year-class in the catches. The catch rates in the offshore fishery were good but with few sea-days.

During the 2011-12 fishing season vessels >20 m noted that the average size of fish caught were smaller than in the previous fishing year. There were few large fish in the catch. The average length was about 55cm and average weight about 1.7kg. The total catch by larger vessels >30m was reduced because of fishing vessel operational issues during the winter season.

CONCLUSIONS AND ADVICE

The assessment concluded from tagging data and ancillary information that the complex of stock components exploited by fisheries in 3Ps does not comprise a single stock for which population biomass and abundance can be estimated from existing information. Therefore the impacts of fishing at specific TAC levels on all stock components could not be quantified. However, the DFO RV survey covers most of the stock, and survey trends broadly reflect stock trends. The estimates of population size and mortality are based upon change in the stock as measured by the DFO RV survey, and are independent of actual landings and TACs, and also independent of the increasing gap between the landings and the TAC. Indices based on the research vessel (RV) survey have been used to assess current status of the stock relative to historic observations and to evaluate growth and sustainability of the stock.

A limit reference point (LRP, $B_{Recovery}$) was identified for this stock during the 2004 assessment (DFO, 2004). It is defined as the lowest observed spawning stock biomass (SSB) from which there has been a sustained recovery; the 1994 value of SSB has been identified as the LRP.

Over 2009-2012, SSB has increased considerably. The SSB was estimated to be below the LRP during 2008 and 2009. The 2012 estimate is 64% above the LRP, and the probability of being below the LRP in 2012 is very low (0.01).

Three-year projections were conducted assuming future mortality rates were within ±20% of current values (2009-11 average). Results indicated that SSB will increase if total mortality is reduced, and remain relatively stable if mortality remains at current levels. SSB is projected to decrease if total mortality is above current values. Overall, the probability of being below the LRP in 2013 is very low (0.01 to 0.05). By the end of the projection period (2015) the probability of being below the LRP ranges from 0 to 0.16.

Recent recruitment (2004-2009 cohorts) has improved. In particular, the 2006 cohort is estimated to be more than twice the time-series (1983-2012) average. This cohort is expected to be fully recruited to the 2012 fishery.

Estimates of total mortality rate from a cohort model (ages 5-10) over 2007-11 plateaued at 0.67. Total mortality rates reflect mortality due to all causes, including fishing. When the age-specific mortality estimates are weighted by the population number at age, total mortality has been decreasing in recent years, with an average value of 0.50 (40% annual mortality). This mortality is relatively high considering that only half of the 2011/12 TAC was taken.

Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay ranged from 17-31% in 2010 but declined to 9-11% in 2011.

Sentinel gillnet catch rates have been very low since 1999, and the 2011 gillnet index was the lowest in the time-series. Sentinel linetrawl catch rates from the past three years have also been below average. Gillnet catch rates from logbooks of vessels <35' have been stable since 1999. Linetrawl catch-rates decreased over 2006-10, but increased in 2011 and are presently at the time-series average.

Overall, the findings of the current assessment are consistent with those of previous assessments. The 3Ps cod SSB at the beginning of 2012 was estimated to be above the LRP.

Management Considerations

The level of total removals is uncertain but less so in the post-moratorium period. In assessing stock status, it would be useful to better understand the accuracy of total removals. Accurate estimates of recreational fishery landings are also required.

Estimation of MSY-based reference points (FMSY and BMSY) for the 3Ps cod stock will require an assessment framework review including further peer review of the modeling approach used to quantify these reference points.

Management should recognize that cod which overwinter in 3Ps are also exploited in adjacent stock areas (Division 3L and Subdivision 3Pn). Hence management actions in these stock areas should consider potential impacts on 3Ps cod.

Recent results confirmed that closures to protect spawning or mixed-stock aggregations are appropriate.

Consequences of area/time closures should be carefully considered as these may result in higher exploitation rates on the components of the stock that remain open to fishing. The fishery should be managed such that catches are not concentrated in ways that result in high exploitation rates on any stock components.

Management should be aware of within-year variations in the individual weight of cod. Greatest yield can be gained when fish are in peak condition, typically in late fall/early winter, while minimizing the number of individuals removed from the stock.

When average fish size (age) in commercial catches is reduced through either depletion of older cohorts or recruitment of younger cohorts, the numbers of fish removed per ton of landed catch is increased.

OTHER CONSIDERATIONS

Temperature

Oceanographic information collected during the spring DFO RV surveys indicated that near-bottom temperatures throughout NAFO subdivision 3Ps have been warmer over 2009-12 increasing to above normal values. Bottom temperatures in 2011 and 2012 were two standard deviations above normal. Survey catches of cod are generally lower in years when there are relatively large incursions of cold/fresh water from the eastern NL shelf. Furthermore, a significant positive correlation was found between bottom temperature and the survey abundance of cod in depths of 100 m or less. The areal extent of bottom water with temperatures >3°C has remained relatively constant at about 50% of the total 3P area, although actual temperature measurements show considerable inter-annual variability. The current conditions are comparable to those of the late 1970's and early 1980's when the stock was more productive.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of October 9-11, 2012 on the Atlantic Cod in Subdivision 3Ps. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www. dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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